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Nutritional and physicochemical properties of stored solar-dried cowpea leafy vegetables

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Abstract

Preservation techniques for cowpea (*Vigna unguiculata* L.) leaves, a green leafy vegetable mainly consumed in the eastern and northern parts of Uganda, are still lacking. The study aimed at determining the effect of blanching, open sun and solar-drying on the nutrient content, organoleptic acceptability and physicochemical properties of cowpea leafy vegetables (CLV) during storage. Proximate composition, sensory quality and colour of the CLV were determined. No significant differences ($p < 0.05$) in nutrient composition were observed between drying methods, except the dietary fibre, zinc and total carotenoid content. Blanched-solar dried CLV showed higher dietary fibre and total carotenoid content compared to raw dried CLV. No significant differences ($p > 0.05$) in appearance, taste, flavour, and texture of dried CLV were observed, except for the fresh CLV (control). Water activity levels ranged from 0.34 to 0.54 indicative of storage stability. Positive 'L' colour values (37.90 to 44.95) indicative of light green to green, negative 'a' values (-7.28 to -4.15) for greenishness and positive 'b' values (3.45 to 9.25) for yellowishness for raw-dried and blanched green leafy cowpea vegetable, respectively, were obtained. Marked increases in browning index and total colour difference were observed in the dried CLV during storage. Blanching and solar drying treatment formed stable and highly acceptable vegetables during storage, which could be recommended for market.

Key words: Acceptability, colour, nutrient content, *Vigna unguiculata*, water activity

Introduction

Green leafy vegetables such as cowpea, are a very important food group in diets of individuals because of their high

nutritional value (Faber *et al.*, 2007; Muchoki, 2007; USDA, 2008). They are not only rich in nutrients, but also nutraceuticals and antioxidants such as alpha tocopherol, lycopenes, flavanoids

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and anticancer agents (Shetty *et al.*, 2013). Cowpea leaves are a delicacy to many households especially in the northern and eastern parts of Uganda (Rubaihayo, 1995; Okonya and Maass, 2014). Fresh cowpea leaves are eaten as accompaniments to main dishes, or as sauce and contribute to the health, nutrition, food security and well-being. The vegetables have short growth period, require minimal attention, and are favoured by nutrient-rich soils (Bok *et al.*, 2006; other REF.).

Recommendations have been made to dry and preserve leafy vegetables as a way of ensuring continued supply of food and micronutrients to communities and groups at risk of malnutrition or food insecurity (Kiremire *et al.*, 2010). Sufficient daily consumption of vegetables could help prevent major diseases, such as cardiovascular diseases and certain cancers (WHO, 2013). In this regard, cowpea leafy vegetables (CLV) could be preserved when they are in season and fed to children who are singled out as being at high risk of nutrient deficiency (Faber *et al.*, 2007; WHO, 2013) during periods of scarcity. The water content of most of fresh vegetables including cowpea, however, is above 80% (FAO, 1995), which limits their shelf-life and makes them more susceptible to storage and transport instability. Processing and preservation methods such as open sun drying and solar drying have been successfully utilized to dry fruits and vegetables such as mushrooms (Addis *et al.*, 2009). As stated by Singh and Sagar, (2010), processing by dehydration makes leafy vegetables light and can be easily re-converted into fresh-like form for consumption throughout the year.

Even though sun drying is traditionally used to dry steamed cowpea leaves in

Uganda, changes in nutrient and organoleptic attributes as well as storage properties for the dried vegetables, have not been determined. The study was undertaken to evaluate the effect of blanching, open sun drying and solar drying on the nutrient composition, physicochemical properties and acceptability of CLVs.

Materials and methods

Material source and processing site

Freshly harvested tender cowpea leaves at 6 weeks after planting, obtained from cowpea farmers in Ngora district, Ngora village, Ngora sub-county in eastern Uganda were processed at a homestead and immediately packaged in HDPE gauge 30 microns. Part of the dried samples packaged in HDPE were delivered to National Agricultural Research Laboratories (NARL), Kawanda Kampala, for proximate, organoleptic and physical tests. Dried and fresh (control) cowpea leaves were organoleptically tested in Ngora, an area where people consume cowpea leaves as a local vegetable, to determine their acceptability.

Sample preparation

About 2 kg of fresh green cowpea leaves, free from insect damage, plucked from plant stalks, were washed in plenty of clean rain water which was available at the study site to remove dirt and spread on a raised wire-mesh to drain excess water. The leaves divided into four portions for blanching in water or no blanching, and then drying.

Processing

a) Blanching. Clean cowpea leaves (1 kg) were placed in a clean saucepan of

30 cm diameter, containing 250 ml of boiling water, covered with a lid, and blanched for 5 minutes on a hot charcoal stove with occasional stirring. After 5 minutes, the CLVs were removed from the charcoal stove and spread on a plastic drying wire-mesh.

b) Drying. The raw unblanched and the blanched cowpea leaves were each subdivided into two. The leaves were spread on 2 m² plastic wire-mesh drier racks and dried either in the open sunshine or solar drier to moisture content 6.0 - 8.7% when both the leaves and stalks were completely dry and easy to crush to tiny pieces. The drying time was 9 -12 hours on hot sunny days and 21 -24 hours during the wet days.

(c) Packaging. Dried CLVs, were packaged in high density polythene of gauge 200, immediately upon removal from the sunshine; and sealed to prevent moisture re-absorption. The packaged vegetables were kept at room temperature in dark-coloured blue buckets to protect from light.

Physicochemical and nutrient analysis

Moisture was determined by drying approximately 2.0 g of fresh sample in a hot air oven at 105 °C for 2 hours following specified methods (Ranganna, 1986; AOAC, 1999; FSSAI, 2012). Dry matter content was calculated by difference. Fat, total carbohydrates, dietary fibre, ash and protein were determined using AOAC (1999; 2005) methods. Fat was determined by the Soxhlet method; total carbohydrate by a spectrophotometric method; dietary fibre by the acid digestion method; ash by the ashing method at 250°C for 6 hours; protein by the Micro-Kjeldahl method and the percentage of

nitrogen was converted to crude protein by multiplying by 6.25. Micronutrients iron, phosphorus, zinc, magnesium, calcium, sodium and potassium were determined by atomic absorption spectrophotometric method (AOAC, 1999) using Atomic absorption Spectrophotometer (Buck Scientific model 200A).

Colour was determined according to Abbott (1999) and Pankaj *et al.* (2013). The colour was measured using a Minolta Colour meter, Model CR 10, and values L, a, and b were determined where 'L' indicated lightness, 'a' the degree of red (+a) and greenness (-a); while 'b' indicated yellow (+b) and blue (-b) colour ranges (Martins *et al.*, 2002; Pathare *et al.*, 2013). The browning index and total colour difference (TCD) were calculated based on methods reported (Pathare *et al.*, 2013).

$$\text{Browning index} = 100 X \left(\frac{X - 0.31}{0.17} \right)$$

Where:

$$X = \frac{(a * +1.75L)a}{(5.645L + a * -3.012b *)}$$

Water activity was determined at ambient conditions, using a Bench-top Water Activity Meter, Model AquaLab, Series 4TE.

Acceptability

The acceptability of the CLV was determined using a 24-member controlled panel. Cooked freshly harvested CLV were used as a control. Samples were prepared for panel testing using a traditional preparation method used in the north and eastern of Uganda. Approximately one mug of thinly crushed dry cowpea leaves was poured into 2000

ml of clean boiling rain water, to which 20 ml of 'legume plant extract, also known as 'kado-buru' or 'kedo-atwona' in Luo, was added to enhance softening of the leaves during cooking. Fresh harvested CLV (about 0.2 kg) were spread in sunshine for about 40 minutes as a pre-treatment prior to boiling in water. The leaves were cut using a sharp stainless steel knife into small pieces (~ 2 cm) and boiled in 2000 ml rain water containing 'kedo-atwona' for approximately 30 minutes until ready and placed aside.

Regular consumers of cowpea vegetables were selected as panelists. Small portions (about 3 table-spoonfuls) of cooked samples were served to the panelists at ambient temperature (25 – 27 °C). Panelists tested the appearance, taste, flavor, texture and overall acceptability of CLV by rating them on a 9-point hedonic scale, where, 9=liked extremely and 1=disliked extremely.

Statistical analysis

Mean and standard deviations were generated using SAS (2000) and XLSTAT (2012). Duncan's multiple range test was used to assess the mean significant differences at $p \leq 0.05$. Coefficients of variation were generated using XLSTAT.

Results and discussion

Nutrient composition

Tables 1 and 2 show the nutrient composition for dried cowpea leafy vegetables (CLV). Raw open sun-dried CLVs contained higher iron, zinc and total carotenoid than other treatments. No significant differences ($p > 0.05$) were observed in moisture, protein, carbohydrate, fat and ash contents. Iron, calcium and phosphorus content were not significantly different ($P > 0.05$). The magnesium, zinc and total carotenoid contents, however, were significantly different ($p < 0.05$) among treatments. The high iron content in open sun-dried CLVs might be due to contamination with dust from the environment, which also has been reported by Singh *et al.* (2010). The differences in provitamin A carotenoid content might be due to losses during drying and heat pre-treatment. Total provitamin A carotenoids, as explained by Addis *et al.* (2009), are significantly reduced by drying methods.

The iron, phosphorus, potassium and calcium composition for dried cowpea leaves were not significantly different ($p < 0.05$), except the magnesium, zinc and total carotenoid content (Table 2). This

Table 1. Proximate macronutrient composition for the dried cowpea leafy vegetable

Vegetable type	Moisture (g)	Protein (g)	Carbo-hydrates (g)	Fat (g)	Fibre (g)	Ash (g)
Blanched, solar dried cowpea leaves	6.31 ^a	28.07 ^b	21.65 ^{ab}	1.92 ^{ab}	29.48 ^a	11.00 ^a
Blanched, open sundried cowpea leaves	7.04 ^a	29.09 ^{ab}	20.73 ^{ab}	2.28 ^a	29.31 ^a	10.67 ^a
Raw, open sundried cowpea leaves	7.35 ^a	30.12 ^a	20.12 ^b	1.90 ^{ab}	19.57 ^b	10.84 ^a
Raw, solar dried	7.29 ^a	29.40 ^{ab}	23.56 ^a	1.68 ^b	17.10 ^b	10.60 ^a

* Values followed by the same superscript letter with a column are not significantly different

Table 2. Proximate micronutrient composition for the cowpea leafy vegetable

Category	(mg/100 g)						
	P	K	Ca	Mg	Fe	Zn	Total carotenoids
Raw, open sun dried	0.329 ^a	4.923 ^a	1.484 ^a	0.217 ^{ab}	764.878 ^a	885.967 ^a	43.680 ^{ab}
Blanched, open sun dried	0.282 ^{ab}	4.554 ^a	1.501 ^a	0.225 ^a	531.984 ^a	682.436 ^b	34.855 ^{ab}
Raw, solar dried	0.279 ^{ab}	4.759 ^a	1.376 ^a	0.241 ^a	576.154 ^a	519.745 ^c	30.095 ^b
Blanched, solar dried	0.267 ^b	4.245 ^a	1.612 ^a	0.182 ^b	443.146 ^a	418.516 ^c	54.635 ^a

* Values followed by the same superscript letter within a column are not significantly different

possibly indicated that processing had no effect on micronutrient content, apart from Mg, Zn and total carotenoids. High Zn content in open sun-dried CLV was probably due to air contamination.

Water activity

The water activity, a_w , for CLV (Fig. 1) was not significantly different among treatments ($P > 0.05$). a_w values ≤ 0.6 , attained within the different treatments were sufficient enough to keep the vegetables in dry condition once well packaged (Cano-Chauca *et al.*, 2004). The level was within the range (<0.6) permitted for storage and preservation of dry foods as suggested by FAO (1995) and Cano-Chauca *et al.* (2004). As explained FAO, 1995; Bonazzi and Dumoulin, 2011), low moisture and water activity (<0.5) are important to prevent physical-chemical and microbiological alterations that could occur during storage of a food product, hence ensuring product preservation.

Differences in water activity content were possibly due to re-absorption or loss of moisture during storage. No significant differences ($p > 0.05$) were observed in water activity for dried packaged CLVs during storage between zero and one month (Fig. 1). Results possibly indicate shelf-stable products that would not be prone to fungal attack and spoilage.

Colour

Colour is an important quality attribute of food, which influences consumers' choice and preferences (Pathare *et al.*, 2013). Colour measurement of food has been used as an indirect measure of other quality attributes, such as flavour and contents of pigments because it is simpler, faster and correlates well with other

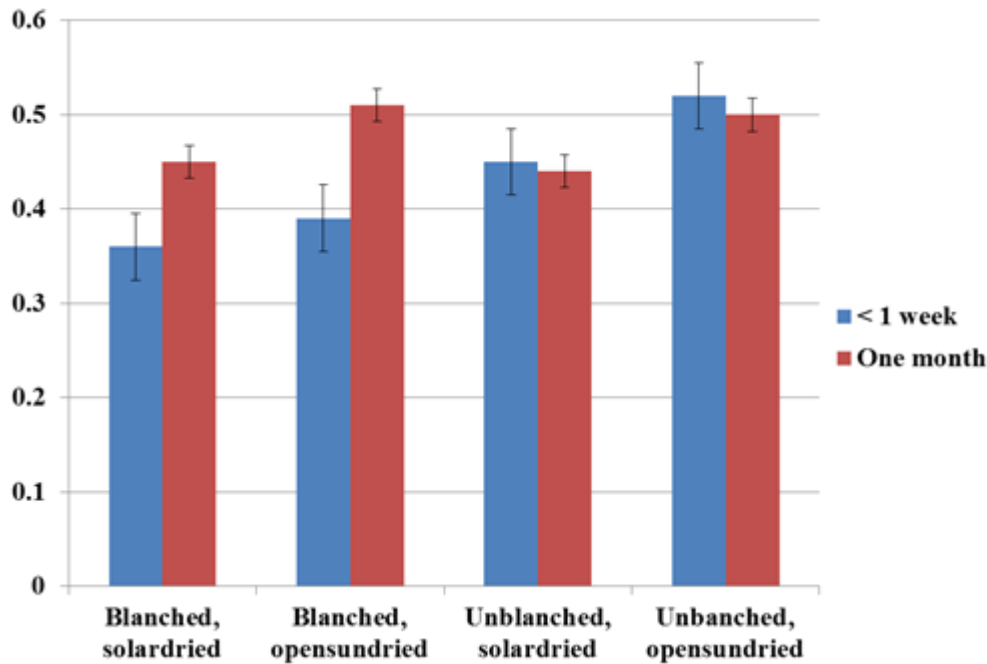


Figure 1. Effect of processing method and storage duration on water activity of dried cowpea vegetables.

physicochemical properties, such as appearance (Pathare *et al.*, 2013).

Changes in colour were not definite after one month, save for the rise in L^* and b^* values (Table 3). An increase in the positive b^* values was a result of loss in colour (increasing yellowness) during drying, which could be explained by the loss of pigments such as chlorophyll and carotenoids from the leaves, caused by the two processes, blanching and drying (Kidmose *et al.*, 2005). Positive increase in a^* values (i.e. reduction in negative a^* values) was noticeable after storage of one month, which could be indicative of loss of the green colour and a result of browning upon processing and storage. In general, raw dried vegetable leaves were lighter green (higher 'L' values; increasingly -ve 'a' values) and yellow (higher + b^* values) than blanched cowpea leaves after drying. Dried blanched

vegetable leaves were dark (high +ve 'a' and more -ve 'b' values) after drying compared to fresh uncooked leaves; this was also confirmed with negative 'Hue' values and high Total Colour Differences (TCD). The dark colour in blanched CLVs could be explained by retention of plant pigments and the destruction of browning enzymes in blanched leaves, which would otherwise cause browning (Pathare *et al.*, 2013).

Large negative browning index values were observed in 'dried raw' compared to 'dried blanched' vegetables (Table 3). The large negative browning index values could be due to the increase in formation of brown pigments by enzymatic browning, as well as oxidation reactions enhanced by sunshine in unblanched CLVs (Pathare *et al.*, 2013). Largely negative browning indices could further be explained by the long duration of exposure

Table 3. Mean values (\pm SErrors) for colour changes in dried cowpea leafy vegetables during storage

Type of vegetable < 1 week after drying	L	a	b	Yellowness index	Browning index	TCD ¹	Hue
Raw solar dried	44.80 \pm 1.62 ^a	-6.65 \pm 0.40 ^b	9.25 \pm 1.10 ^a	29.43 \pm 2.44 ^a	-1467.87 \pm 89.65 ^b	6.87 \pm 1.97 ^a	-6.31 \pm 2.83 ^b
Blanched, solar dried	37.90 \pm 1.16 ^b	-4.25 \pm 0.17 ^a	3.95 \pm 0.17 ^b	14.88 \pm 0.20 ^b	-966.93 \pm 32.23 ^a	2.96 \pm 0.53 ^b	-1.34 \pm 0.01 ^a
Raw, open sun dried	45.60 \pm 0.14 ^a	-7.28 \pm 0.13 ^c	9.00 \pm 0.26 ^a	28.19 \pm 0.75 ^a	-1573.98 \pm 6.77 ^c	7.61 \pm 0.23 ^a	-2.89 \pm 0.17 ^a
Blanched open sun dried	39.30 \pm 0.23 ^b	-4.15 \pm 0.06 ^a	3.45 \pm 0.17 ^b	12.54 \pm 0.56 ^c	-943.37 \pm 12.01 ^a	3.25 \pm 0.13 ^b	-1.10 \pm 0.07 ^a
After one month storage							
Raw solar dried	43.90 \pm 1.16 ^a	-6.55 \pm 0.06 ^c	8.50 \pm 0.35 ^a	27.65 \pm 0.40 ^a	-1437.81 \pm 14.60 ^c	5.73 \pm 1.19 ^a	-3.63 \pm 0.58 ^b
Blanched, solar dried	42.15 \pm 0.29 ^b	-5.80 \pm 0.12 ^b	7.50 \pm 0.02 ^b	25.42 \pm 0.17 ^c	-1288.88 \pm 20.38 ^b	3.66 \pm 0.28 ^b	-3.54 \pm 0.35 ^b
Raw, open sun dried	45.15 \pm 1.33 ^a	-6.45 \pm 0.17 ^c	8.40 \pm 0.46 ^a	26.56 \pm 0.68 ^b	-1416.26 \pm 36.90 ^c	6.84 \pm 1.42 ^a	-3.68 \pm 0.53 ^b
Blanched open sun dried	39.38 \pm 0.57 ^c	-4.25 \pm 0.19 ^a	3.58 \pm 0.32 ^c	12.96 \pm 1.05 ^d	-962.32 \pm 36.57 ^a	3.15 \pm 0.27 ^b	

Values with the different superscript letters in the same columns are significantly different ($p < 0.05$)

¹ TCD = Total colour difference

Table 4. Organoleptic scores for cooked dried cowpea leafy vegetables used in a drying and storage study Ngora, Uganda

Cowpea leaves type	Attribute scores				
	Appearance	Taste	Flavour	Texture	Overall acceptability
Blanched, solar dried	6.458 ^b	6.708 ^b	6.208 ^b	5.625 ^b	6.542 ^b
Blanched, open sun-dried	6.125 ^b	5.917 ^b	5.458 ^b	4.542 ^b	5.833 ^b
Raw, solar dried	6.708 ^b	5.833 ^b	5.625 ^b	5.042 ^b	5.667 ^b
Raw, open sun-dried	6.542 ^b	6.083 ^b	5.500 ^b	5.500 ^b	6.292 ^b
Fresh leaves (control)	8.250 ^a	7.875 ^a	7.708 ^a	7.333 ^a	7.958 ^a

to sunshine (Demirhan *et al.*, 2009), of vegetables under drying. It is notable that the drying time ranged between 9 to 24 hours depending on the weather. Lengthy drying time was possibly contributory to browning reactions in CLV.

Acceptability

Sensory evaluation could be considered the most important aspect of food quality. It reflects consumer preference. Sensory evaluation of vegetables brings about very valuable information on quality characteristics and level of acceptability with a consequence on adoption potential. According to Abbot (1999) and Eze *et al.* (2012), sensory traits of vegetables are the main factors that determine consumer's satisfaction.

Apart from the control, dried cowpea leaves were not significantly different ($p > 0.05$) in appearance, taste, flavour, texture and overall acceptability. Blanched solar dried CLVs were comparatively more acceptable in taste, flavour and texture than the blanched open sun dried, raw-sundried and raw-solar dried CLVs. Blanched solar dried CLVs were however less acceptable than the control, which may explain the negative effects of processing on leafy vegetable taste and

flavour changes. Sensory tests showed that panelists liked blanched solar dried CLV especially for its taste and flavor. Raw-dried CLVs were moderately liked for appearance, but only slightly liked for flavour, taste and texture. This could be explained by the deterioration in taste, flavour and texture of vegetables due to open sun drying (Addis *et al.*, 2009) and enzymatic reactions (Kidmose *et al.*, 2005).

The relatively natural green colour after cooking could explain the average high appearance scores for un-blanched leafy vegetables. This finding relates to results of the colour (Table 4), whereby raw dried leafy cowpea leaves featured with high positive 'b' values indicative of green. Analysis of variance showed that taste and texture were important in deciding the acceptability of dry processed vegetables ($p < 0.05$). Overall, blanched solar dried cowpea leafy vegetables were liked more than the other treatments.

Conclusion

Blanching combined with solar drying enriches the taste, flavor, texture and storage stability of cowpea leafy vegetables (CLVs), but not the

appearance and colour. Blanched CLVs are highly acceptable, implying that blanching is a necessary pre-treatment in vegetable drying, which enhances flavour, taste and texture.

Solar drying and open sun drying technologies result into moisture-stable and low water activity which can ensure stability of dried vegetables even after drying. Preservation of leafy vegetables using open sun or solar drying should preferably be done when the sunshine is intense enough to cause fast drying, prevent browning and loss of flavours.

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